



# Otway Project: Multi-Purpose Borehole Seismic Sensors;

Design, Installation and  
Preinjection Monitoring Data

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# Outline

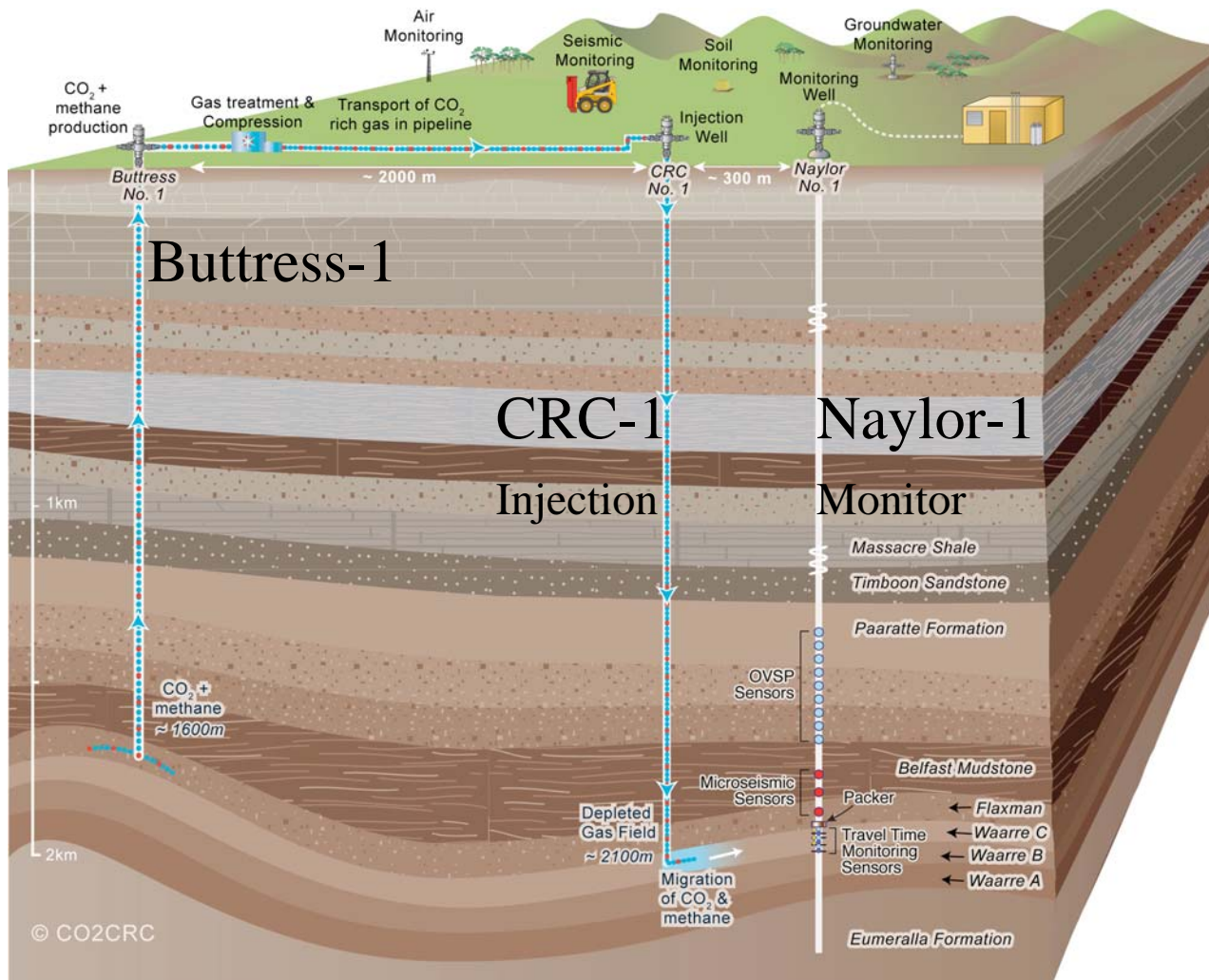


- **Otway Project Background and Status**
- **Design of Monitoring well instrumentation**
- **Installation Challenges**
- **Preinjection Monitoring**
  - **Microseismic**
  - **Active Source Seismic**

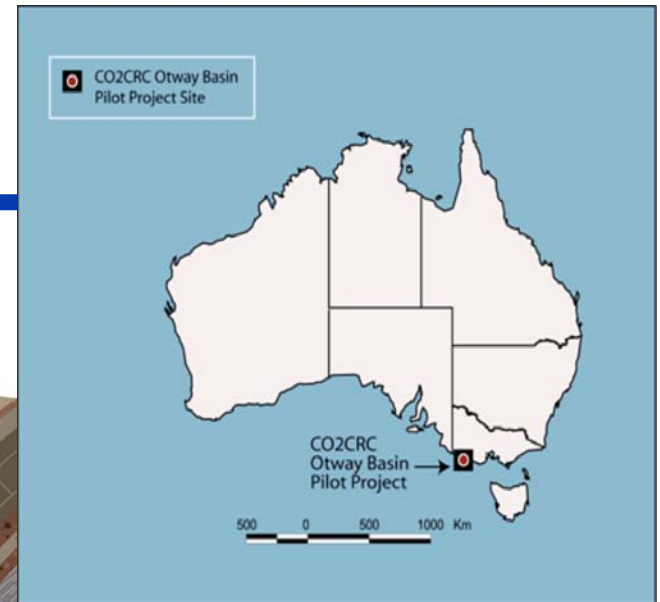


CRC-1 Injection Well

# Otway Project: Depleted Gas Field



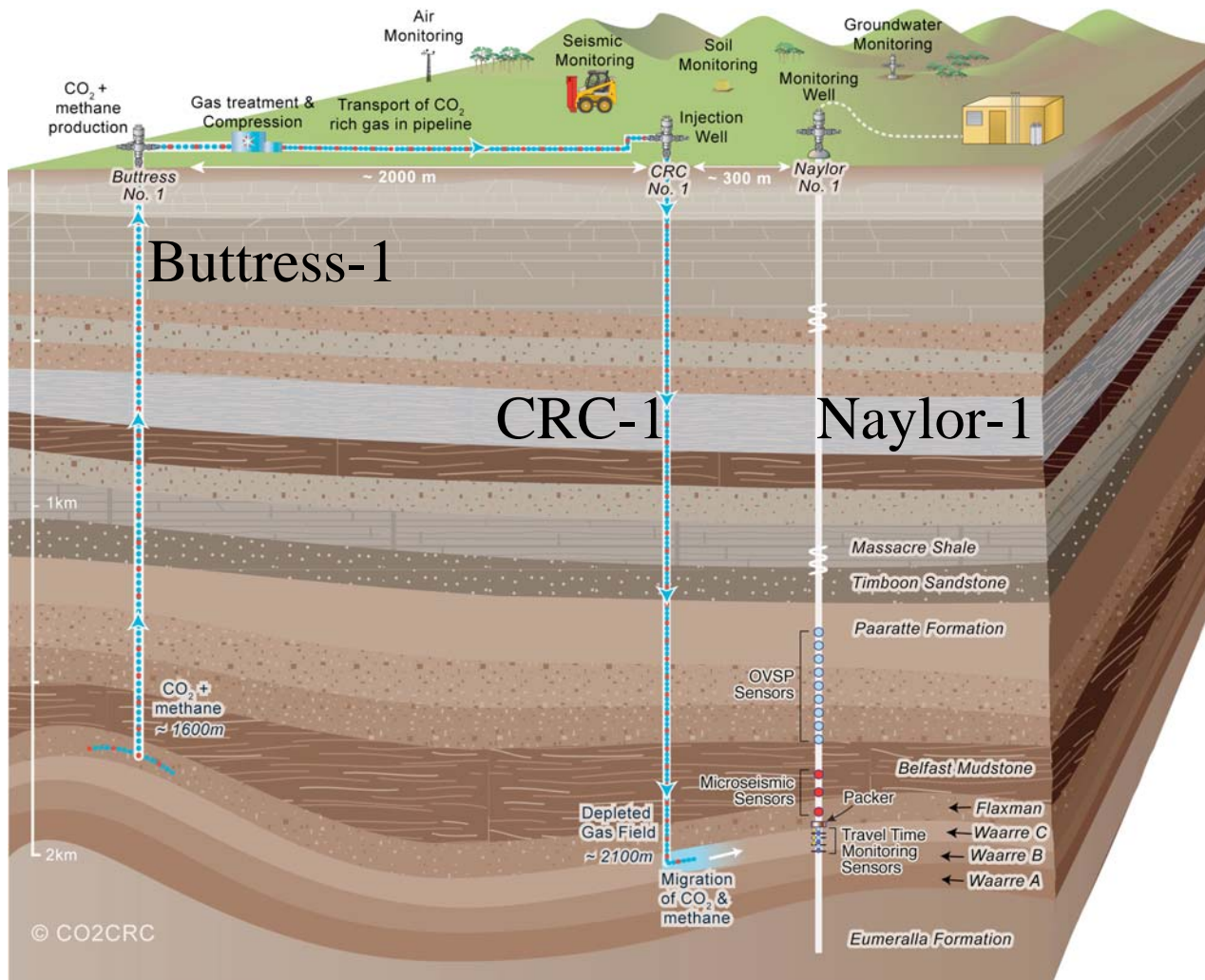
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## Basic Plan:

- ~ 2 km Depth
- Natural source of CO<sub>2</sub>; preexisting wells for production & monitoring
- New Injection Well
- Expected seismic change is small - want permanent instrumentation

# Otway Project: Depleted Gas Field



- Buttress-1 Produces 80% CO<sub>2</sub> 20% CH<sub>4</sub>
- Compress and transport 2 km
- Inject 100,000 tonnes over 2 years (1 kg/s)
- Surface Monitoring:
  - soil and atmospheric gas sampling
  - 4D surface seismics and VSP
- Naylor-1 borehole monitoring:
  - seismic and geochemical fluid;



# Otway Project Current Status



- Injection began April 2, 2008
- 3,700 tonnes injected as of April 29, 2008
- Currently injecting ~100 tonnes/day

CRC-1 Injection Well



Naylor-1 Monitoring Well



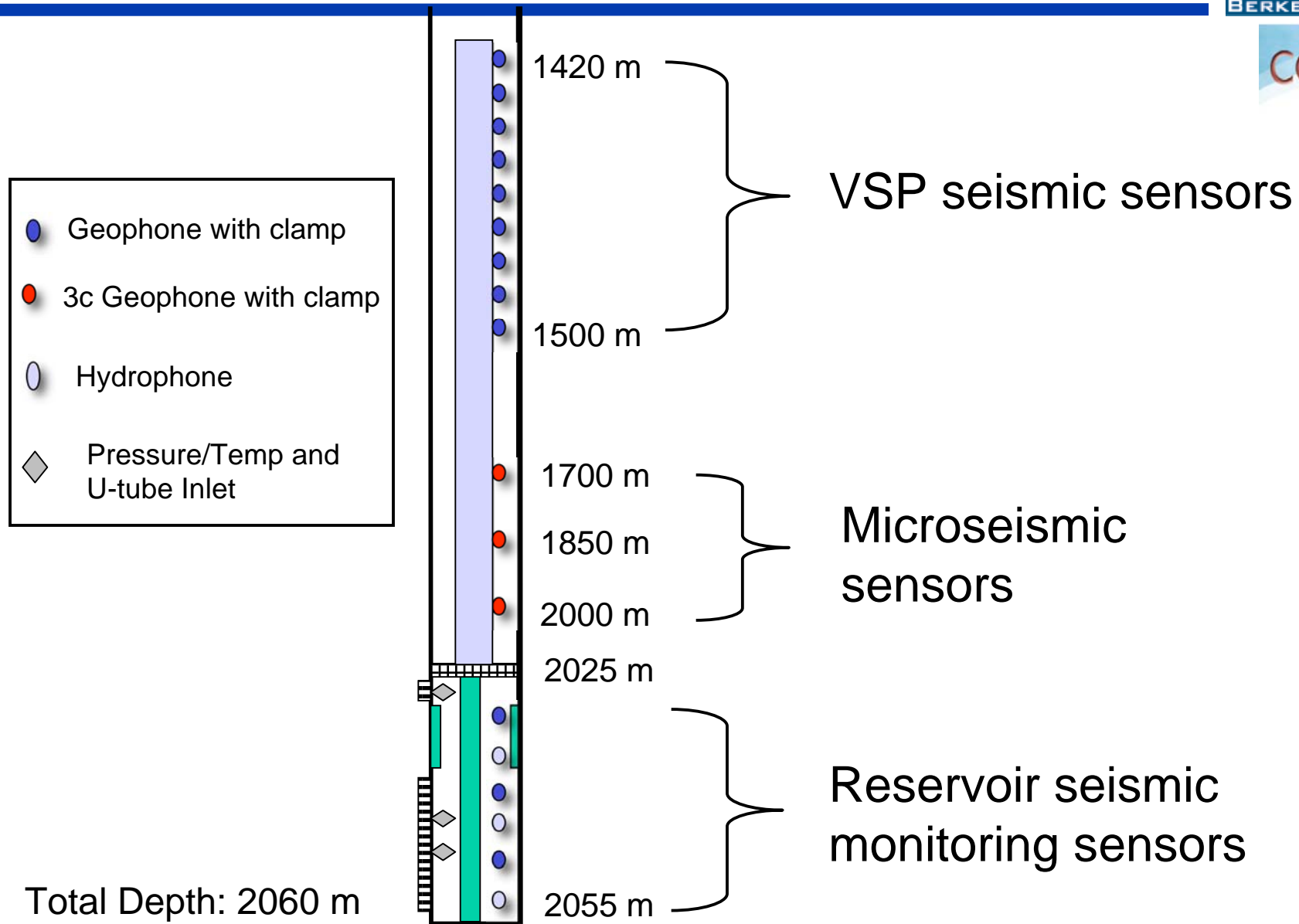
# Goals of Monitoring Well Instrumentation

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- **Semi-permanent installation (removed for P&A)**
  - **Periodic fluid sampling for geochemistry (~weekly)**
  - **Periodic active source seismic monitoring (~monthly)**
  - **Continuous microseismic monitoring**
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# Design Schematic of Naylor-1 Borehole Monitoring



# Naylor-1 Installation: Technical Challenges



- 2 7/8" borehole with 2 3/8" casing patch restriction
- Want to install 9, 2 km long tubes, control line, sensor cable
- bottom-hole conditions are:
  - Mixed CH<sub>4</sub>, Brine,
  - 85°C, 17.7 MPa
- Collect P/T, seismic data, geochemical samples, for two years
- Installation is a one way trip—coming out of the hole is cost prohibitive.



# Novel equipment and procedures

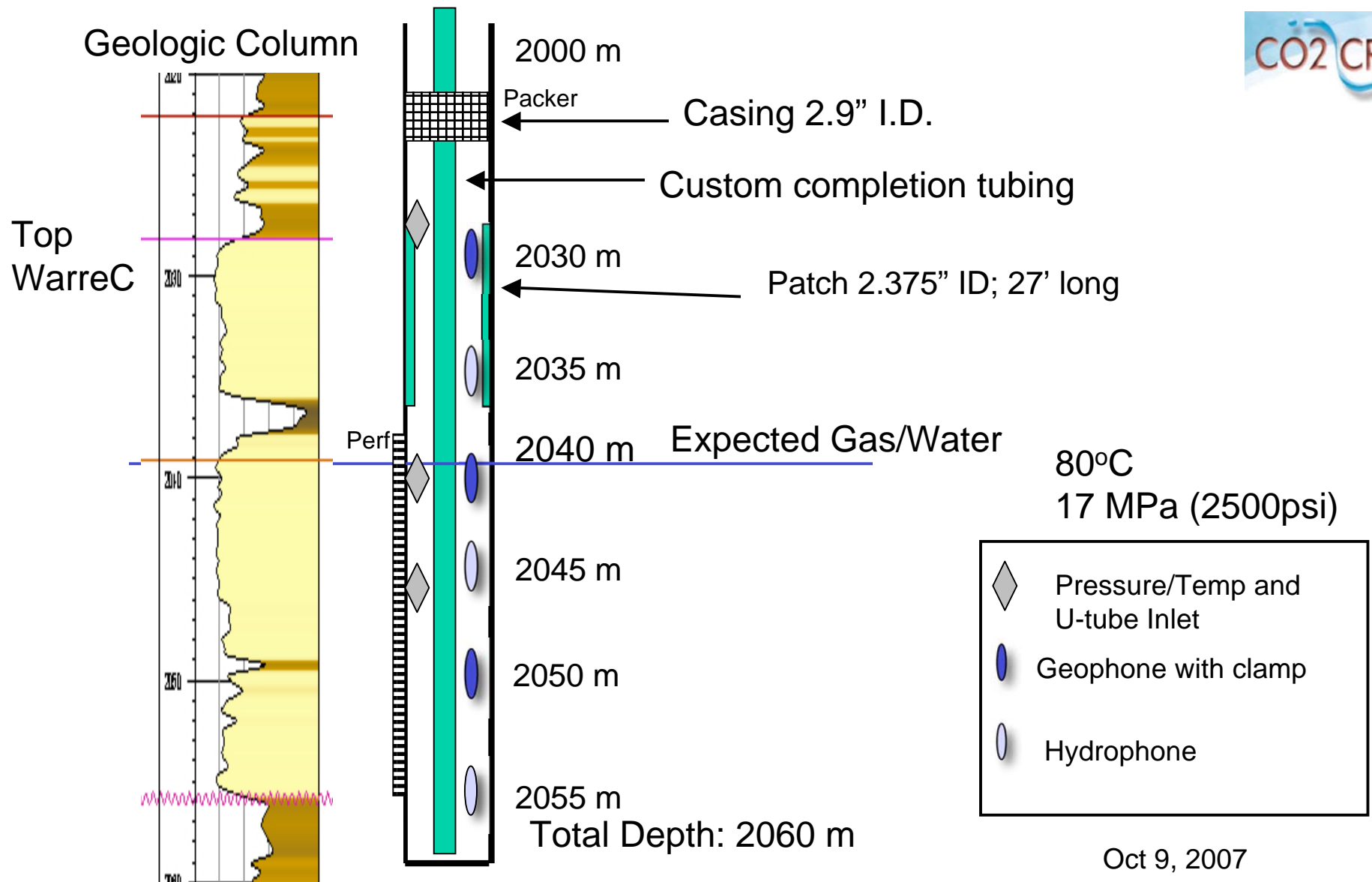


- Sucker rod deployment of instrumentation
  - Joint Protectors, Geophone Bow-Spring Anchors
- Bottom Hole Assembly (BHA)
  - Pneumatic packer
  - 3 U-tubes for sampling
  - 6 seismic sensors
  - 2 P/T gauges
  - ~35 m long, 5 cm tube in ~1.5 m sections
- Many unique processes and issues:
  - Run in hole procedures
  - Well control: kill fluid + shear rams
  - Tubes/cables attached to sucker rods
  - Gas lift to purge kill fluid

Shear Ram Test



# Schematic of bottom hole assembly



Oct 9, 2007

# Geophone with Bow Spring in Bottom Hole Assembly (BHA)

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Geophone

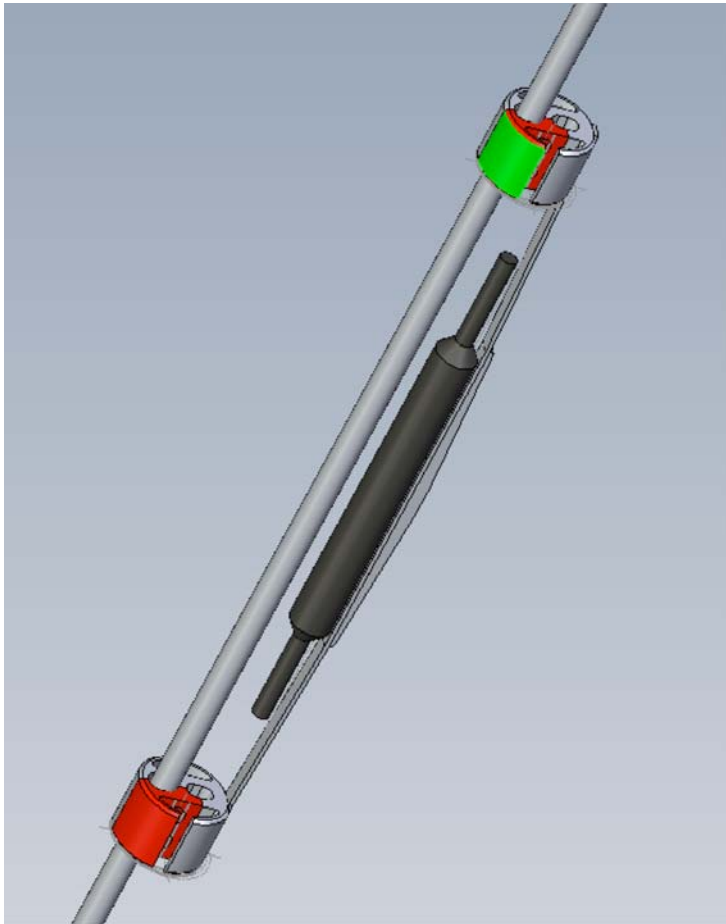
Bow Spring



2" completion tube

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# Sucker Rod Geophone Clamp



Design Drawing



Bow Springs



Rod-Spring  
Clamps



## 24 Hour Rain/Shine Operation: No photos of geophone on sucker rod!

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CO2 CRC





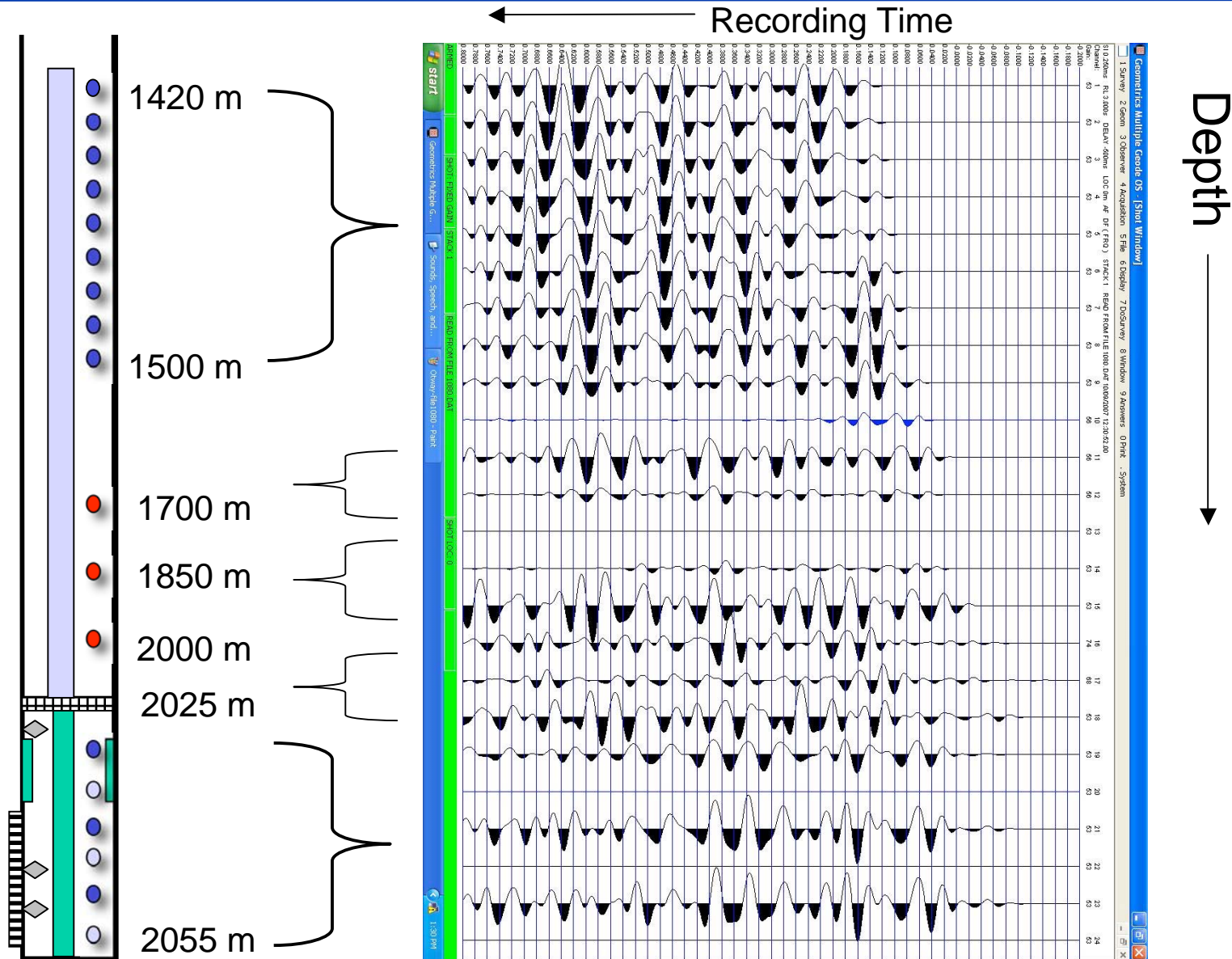
# Bottom Hole Assembly and Rod Deployment



- Vertical BHA lift: 3 cranes (incl. 48 m crane) and 1 man-lift
- ~4 24-hour days to install
- ~ 260 sucker rods with 5 bands and coupling protector, ~ 10 minutes per rod
- 12 Geophones attached to sucker rod
- 9 stainless steel tubes



## Example of Initial Otway Seismic Data: Probable Source: 'Burp' During Fluid/Gas Production





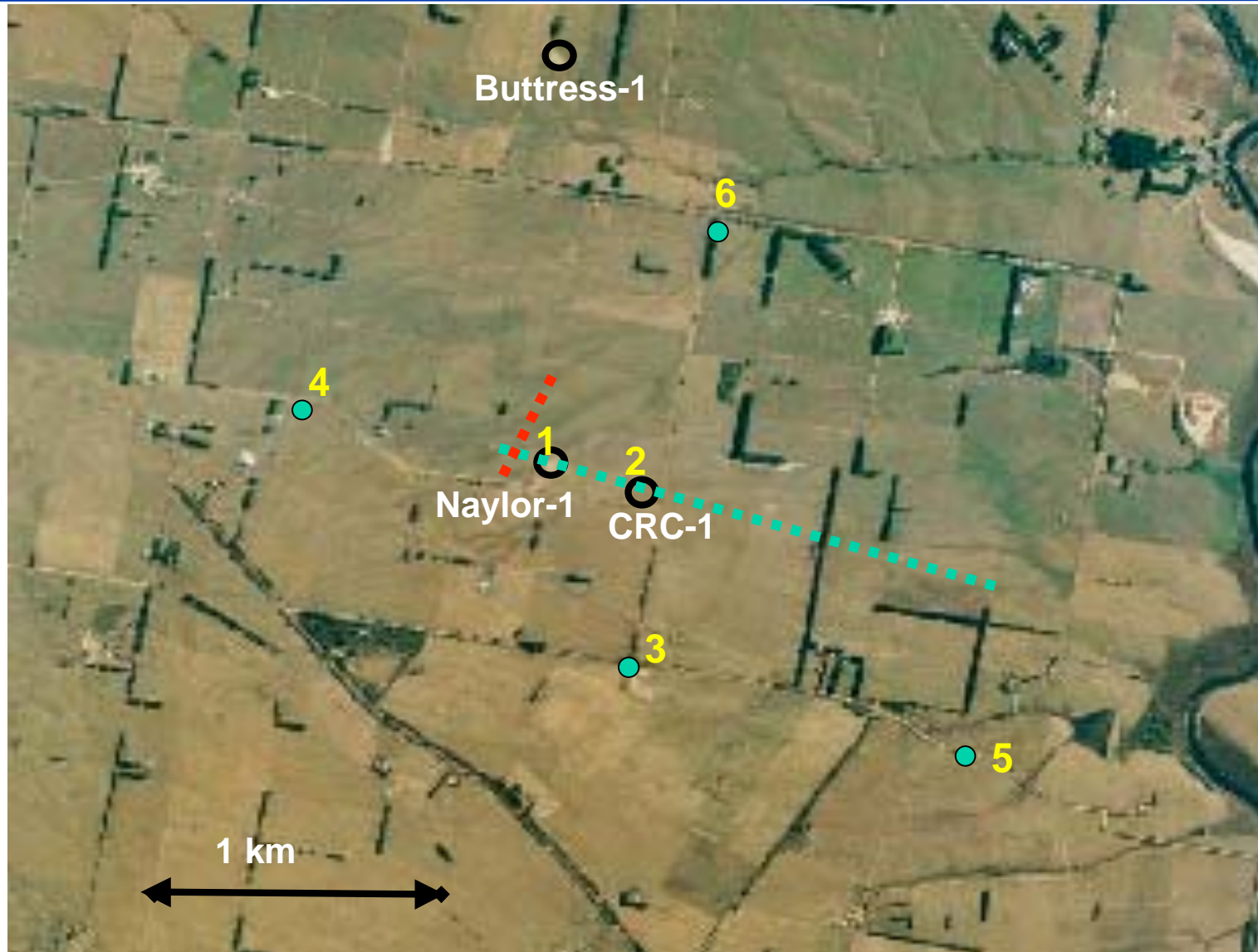
# Permanent Multi-level Geochemical Sampling



Multi-level U-tube geochemical sampling system provides information on the distribution of CO<sub>2</sub> and arrival of gas tracers



# Seismic Monitoring Locations and Nearby Wells



● Shot Point

○ Well

.....  
Walkaway line  
every 20 m

--- Fault



# Initial test: Small Weight drop - poor data.





# Weight drop source on bobcat: Good data, but too many holes!

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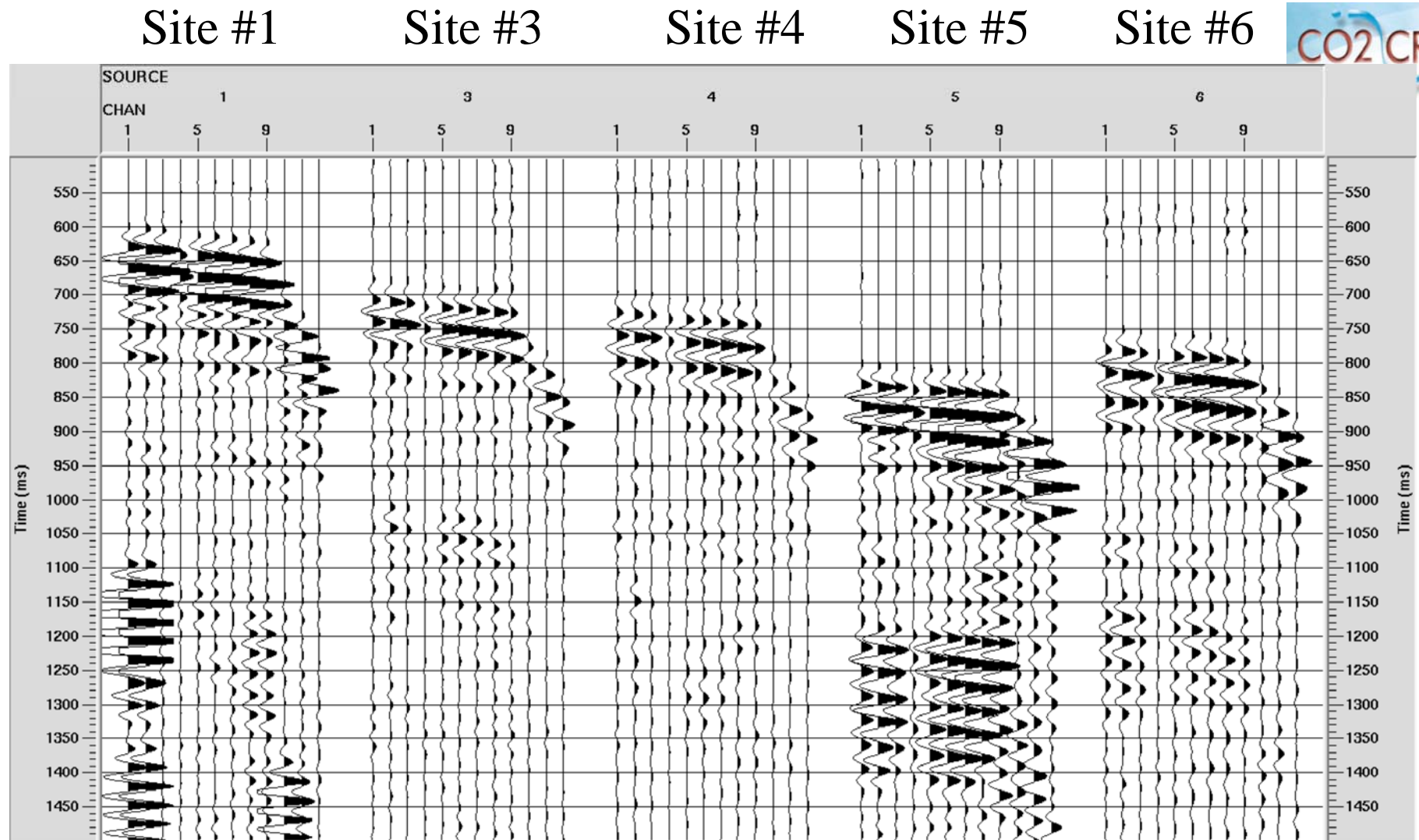
# Explosive Shot Holes: Best Source For Cost, Effectiveness, Surface Damage



Site #3 Dances Rd.: 2 shots of 400g,  
100 mm diameter, 3 m depth

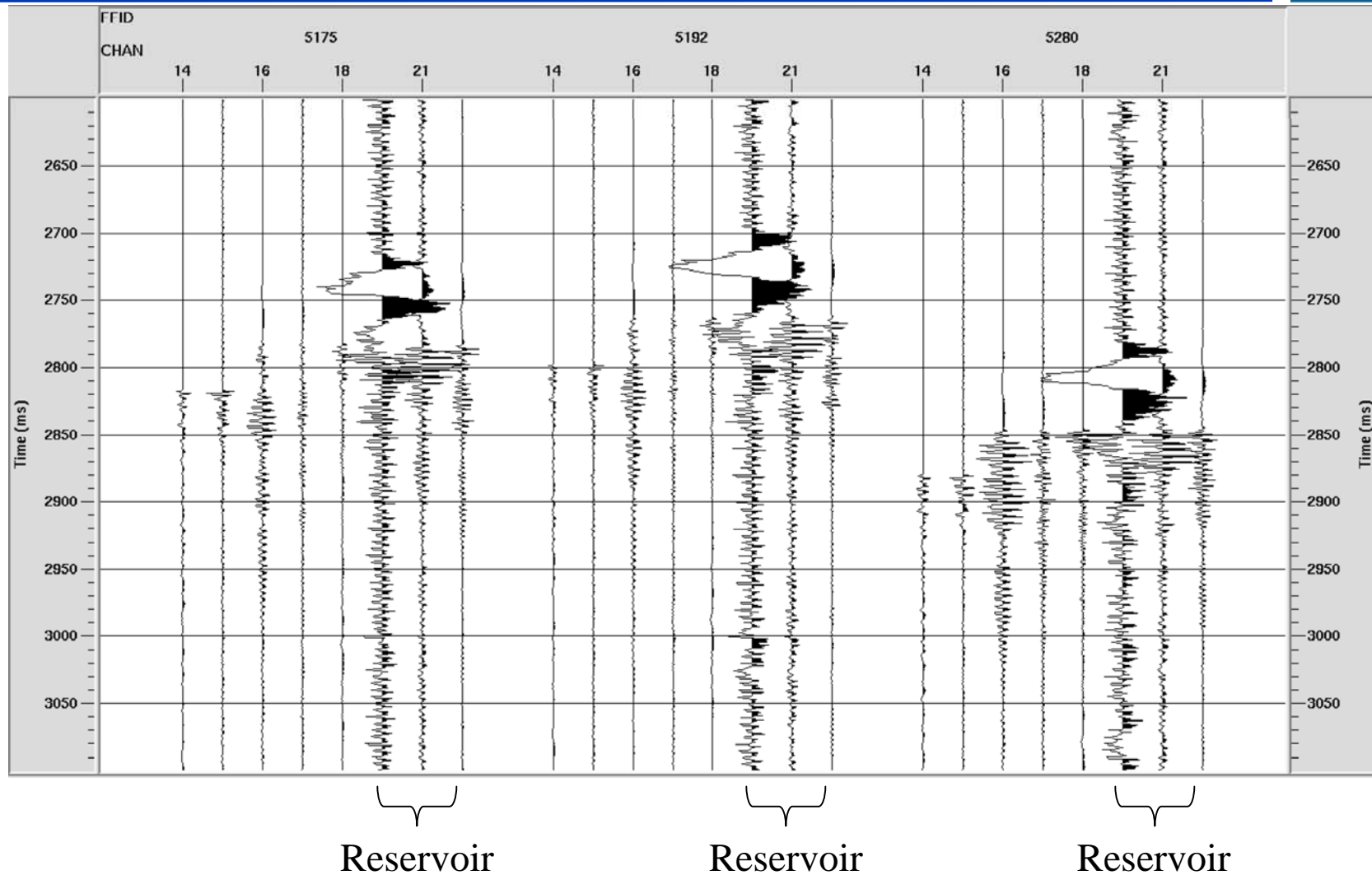
# Shot Hole Data

## Good Quality, except in reservoir





# 3 Perforation Shots in CRC-1 (Injection well) recorded in Naylor-1 (monitor well)



Good data in reservoir!

# Microseismic Event

## Very few events!

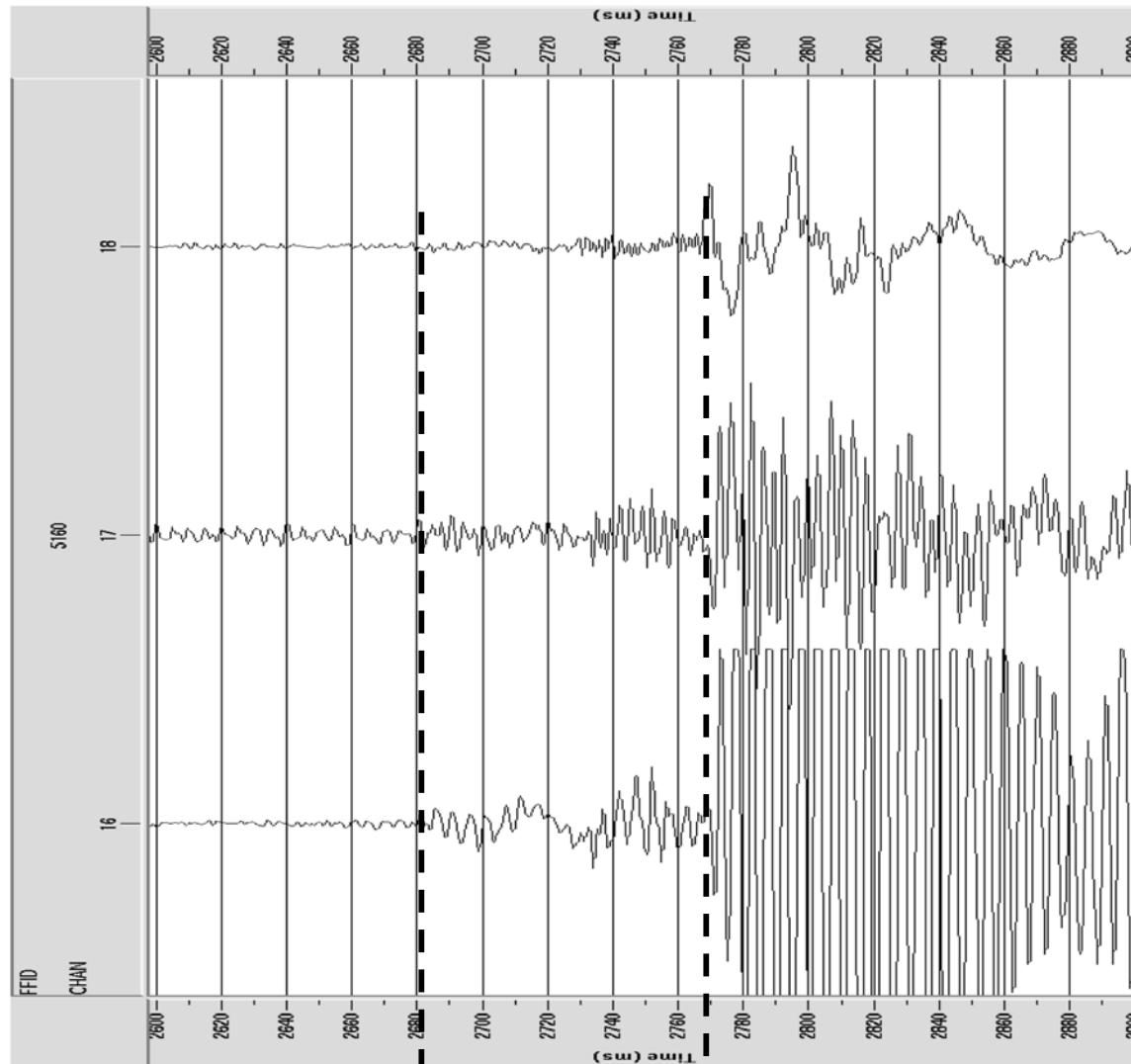


3-component  
sensor at 2000 m

Vertical

Horizontal

Horizontal



P-Wave

S-Wave



# Naylor-1 Seismic Summary

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- **Microseismic**
    - Initial triggered recording shows very few events - not enough to interpret
    - Switched to continuous recording for ~2 weeks during beginning of injection - this data is still being analyzed
    - Currently triggered recording
  - **Active source monitoring**
    - Decided on explosive source
    - Preinjection data from 6 sites looks good for reflection/coda monitoring and leakage monitoring, to be repeated every ~2-3 weeks
    - Walkaway VSP to be extended for better spatial imaging, to be repeated every ~month
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# Summary/Conclusions

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- The Otway project is a prototype for CO2 storage in a depleted gas reservoir.
  - A unique monitoring instrumentation package was designed and deployed.
  - Use of preexisting gas well required specialized procedures.
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# Summary/Conclusions

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- Initial preinjection active source monitoring required testing of various seismic sources.
  - Explosive source found best due to high energy and minimal surface damage.
  - Lack of response from sensors in reservoir will require use of reflected energy for CO2 detection/monitoring.
  - Microseismic monitoring is operational including preinjection characterization - very few events.
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# Acknowledgments



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Supporting participants: [Australian Greenhouse Office](#) | [Australian National University](#) | [CANSYD](#) | [Meiji University](#) | [The Process Group](#) | [University of Queensland](#) | [Newcastle University](#) |